

Claims

1 1. An interconnect structure comprising:
 2 a plurality of interconnected nodes including distinct nodes A, B, C, and D;
 3 data interconnect lines AB₁ and AB₂ coupled from the node A to the node B
 4 for sending data from the node A to the node B;
 5 data interconnect lines CD₁ and CD₂ coupled from the node C to the node D
 6 for sending data from the node C to the node D;
 7 a data interconnect line AD coupled from the node A to the node D for sending
 8 data from the node A to the node D;
 9 means for detecting a condition at the node C;
 10 means for sending a control signal CS from the node C to the node A, the
 11 control signal being determined at least in part by the condition at the
 12 node C; and
 13 means for sending a message M arriving at the node A to the node B or the
 14 node D on a data interconnect line selected from among the data
 15 interconnect lines AB₁, AB₂, and AD depending at least partly on the
 16 control signal CS.

1 2. An interconnect structure according to Claim 1 wherein:
 2 the control signal CS is carried from the node C to the node A on a control
 3 interconnect line from the node C to the node A.

1 3. An interconnect structure according to Claim 2 wherein:
 2 every output port reachable from the node A is reachable from the node C;
 3 further comprising:
 4 an output port that is reachable from node A and is not reachable from the
 5 node D.

1 4. An interconnect structure according to Claim 1 wherein:
 2 the line AD passes directly from the node A to the node D.

1 5. An interconnect structure according to Claim 1 wherein:
2 the line AD passes through a node between the node A and the node D on the
3 line AD.

1 6. An interconnect structure according to Claim 1 wherein:
2 when the condition at the node C is that no messages are moving from the
3 node C to the node D and implicit in a message M at the node A is a
4 condition that a path exists from the node D to a target destination of
5 the message M and the message M has a level of quality of service not
6 less than the threshold of quality of service for the node A to send a
7 message to the node D, then the node A routes a message from the node
8 A to the node D.

1 7. An interconnect structure according to Claim 1 wherein:
2 when the condition at the node C is that a low quality of service (LQOS)
3 message is sent from the node C to the node D and no other message is
4 sent from the node C to the node D then the node A can send a high
5 quality of service (HQOS) message to the node D so long as a HQOS
6 message M is present at the node A and a path exists through the node
7 A to an acceptable output port for the message M.

1 8. An interconnect structure according to Claim 1 wherein:
2 when the condition at the node C is that a HQOS message is sent from the
3 node C to the node D and no other message is sent from the node C to
4 the node D, then the node A can send either a HQOS or LQOS
5 message from the node A to the node D so long as a message M is
6 present at the node A such that the quality of service of the message M
7 exceeds the minimum quality of service level for sending messages
8 from the node A to the node D and a path exists from the node D to an
9 acceptable output port for the message M.

- 1 9. An interconnect structure according to Claim 1 wherein:
2 when the condition at the node C is that the node C sends a message on each
3 line from the node C to the node D, then the node A can send no
4 messages to the node D.
- 1 10. An interconnect structure according to Claim 1 wherein:
2 when the condition at the node C is that a HQOS message and a LQOS
3 message are sent from the node C to the node D, then the node C sends
4 the HQOS message on the data interconnect line CD_1 and the LQOS
5 message on the data interconnect line CD_2 .
- 1 11. An interconnect structure according to Claim 1 wherein:
2 when a message M is sent from the node A to the node D, then the message M
3 is selected from the message set R containing each message at the node
4 A that can reach the target of the message M through the node D.
- 1 12. An interconnect structure according to Claim 11 wherein:
2 no message in the message set R has a higher level of QOS than the message
3 M.
- 1 13. An interconnect structure according to Claim 12 wherein:
2 a message in the message set R with the same level of QOS as the message M
3 is not sent to the node D based on information from the node A.
- 1 14. An interconnect structure according to Claim 12 wherein:
2 the message selecting means selects a message at the node A from the message
3 set R for sending to the node D based on the level of QOS and the node
4 last visited prior to arrival at the node A of the messages in the
5 message set R.
- 1 15. A communication interconnect structure comprising:
2 a plurality of nodes including distinct nodes A, C, and D;

a plurality of interconnect lines coupling the nodes, the node D having one or more message input interconnect lines coupled to the node A and one or more message interconnect lines coupled to the node C; and a logic that enforces priority relationship rules, the priority relationship rules including:
rules governing the sending of messages from the nodes A and C to the node D so that for a message MA arriving at node A and a message MC arriving at node C, the message MC is not blocked from traveling to node D by the message MA; and rules governing the sending of messages from the node A to the node D depending at least in part on quality of service levels of messages at node A.

16. A communication interconnect structure according to claim 15 wherein: the rules governing the sending of messages from the node A to the node D depend at least in part on the number of messages that the node C sends to the node D.

17. A communication interconnect structure according to claim 15 wherein: the rules governing the sending of messages from the node A to the node D depend at least in part on routing by the node D of message arriving at a node subsequent to the node D.

18. A communication interconnect structure according to claim 17 wherein: one or more messages N exist so that when the node C sends a message N to the node D, then the node A is not allowed to send messages to the node D.

19. A communication interconnect structure according to claim 15 wherein: the rules governing the sending of messages from the node A to the node D depend at least in part on the quality of service levels of each of the messages that are sent from the node C to the node D.

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1 20. A communication interconnect structure according to Claim 15 wherein:
 2 the logic that determines the priority relationship associates a threshold value
 3 $T_0(A,D)$ with the pair of nodes A and D; and
 4 the rules specify that when the node C sends no messages to the node D then
 5 the node A sends a message from the node A to the node D so long as a
 6 message M at the node A has a quality of service level greater than
 7 $T_0(A,D)$ and a path exists from the node D to a target of the message
 8 M.

1 21. A communication interconnect structure according to Claim 15 wherein:
 2 the rules specify that when the node C sends no messages to the node D then
 3 the node A sends a message from the node A to the node D so long as a
 4 message M at is present at the node A and a path exists from the node
 5 D to a target of the message M.

1 22. A communication interconnect structure according to Claim 15 wherein:
 2 the rules specify that when the node C sends one LQOS message to the node D
 3 and no other message to the node D, the node A sends one HQOS
 4 message to the node D so long as a HQOS message M is present at the
 5 node A and a path exists through the node D to a acceptable output port
 6 of the message M.

1 23. A communication interconnect structure according to Claim 15 wherein:
 2 the rules specify that when the node C sends one HQOS message to the node
 3 D and no other message to the node D, the node A sends a message to
 4 the node D so long as a message M exists at the node A and a path
 5 exists through the node D to an acceptable output port of the message
 6 M.

1 24. A communication interconnect structure according to Claim 15 wherein:
 2 the logic that determines the priority relationship associates a threshold value
 3 $T_0(A,D)$ with the pair of nodes A and D; and

the rules specify that when the node C sends one HQOS message to the node D, the node A sends a message to the node D so long as a message M exists at the node A such that a path exists through the node D to an acceptable output port of the message M and the quality of service level of the message M is not less than $T_0(A,D)$.

25. A communication interconnect structure according to Claim 15 wherein: the rules specify that when the node C sends one LQOS message to the node D and no other messages to the node D, a HQOS message is sent from the node A to the node D so long as a HQOS message M is available at the node A and the message M can reach an acceptable port of the message M through the node D.

26. A communication interconnect structure according to Claim 15 wherein: the rules specify that when the node C sends two messages to the node D, then no message is sent from the node A to the node D.

27. A communication interconnect structure according to Claim 15 wherein: the rules specify that when the node A sends two messages to the node D, then a message may be sent from the node A to the node D so long as logic that enforces priority relationship rules including logic governing the flow of data through the node A is informed that one or more of the messages traveling from the node A to the node D will be routed through the node D to a node X having the property that an output port that is reachable from the node D is not reachable from the node X.

28. A communication interconnect structure according to Claim 15 wherein the interconnect structure is an hierarchical interconnect structure with messages passing from a previous level to a subsequent level, the nodes C and D being on a level subsequent to the level of the node A, the interconnect structure further comprising:

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6 a data interconnect line A₁ coupled to the node A for receiving high quality of
 7 service data at the node A from a source on the same level as the node
 8 A;
 9 a data interconnect line A₂ coupled to the node A for receiving low quality of
 10 service data at the node A from a source on the same level as the node
 11 A;
 12 a data interconnect line A₃ coupled to the node A for receiving data at the node
 13 A from a source on a previous level to level of the node A; and
 14 a logic associated with the node A that selects messages for transmission to the
 15 node D from a message set arriving at the node A for sending from the
 16 node A to the node D when the condition at the node C permits a
 17 message to be sent to the node D from the node A.

1 29. A communication interconnect structure according to Claim 28 wherein:
 2 the logic associated with the node A selects a HQOS message arriving at the
 3 node A on the data interconnect line A₁ over any other messages in the
 4 message set.

1 30. A communication interconnect structure according to Claim 28 wherein:
 2 the logic associated with the node A selects a HQOS message arriving at the
 3 node A on the data interconnect line A₂ in the absence of a HQOS
 4 message arriving at the node A on the data interconnect line A₁.

1 31. A communication interconnect structure according to Claim 28 wherein:
 2 the logic associated with the node A selects a HQOS message arriving at the
 3 node A on the data interconnect line A₃ in the absence of a HQOS
 4 message arriving at the node A on the data interconnect line A₁ or on
 5 the data interconnect line A₂.

1 32. A communication interconnect structure according to Claim 28 wherein:
 2 the logic associated with the node A selects a LQOS message arriving at the
 3 node A on the data interconnect line A₂ in the absence of a HQOS
 4 message arriving at the node A.

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1 33. A communication interconnect structure according to Claim 28 wherein:
2 the logic associated with the node A selects a LQOS message arriving at the
3 node A on the data interconnect line A₃ in the absence of a HQOS
4 message arriving at the node A or a LQOS message arriving at the
5 node A on the data interconnect line A₂.

1 34. A communication interconnect structure according to Claim 28 further
2 comprising:
3 a data interconnect line A₄ coupled to the node A for receiving data at the node
4 A from a source on a previous level to level of the node A.

1 35. A communication interconnect structure according to Claim 34 wherein:
2 the logic associated with the node A selects a HQOS message arriving at the
3 node A on the data interconnect line A₄ in the absence of a HQOS
4 message arriving at the node A on the data interconnect line A₁, the
5 data interconnect line A₂, or the data interconnect line A₃.

1 36. A communication interconnect structure according to Claim 34 wherein:
2 the logic associated with the node A selects a LQOS message arriving at the
3 node A on the data interconnect line A₄ in the absence of a HQOS
4 message arriving at the node A or a LQOS message arriving at the
5 node A on the data interconnect line A₂ or on the data interconnect line
6 A₃.

1 37. An interconnect apparatus, comprising:
2 a plurality of nodes; and
3 a plurality of interconnect lines selectively coupling the nodes in a hierarchical
4 multiple level structure with the level of a node being determined
5 entirely by the position of the node in the structure in which data
6 moves unilaterally from a source level to a destination level or laterally
7 along a level of the multiple level structure, a plurality of data
8 messages including high quality-of-service (HQOS) messages and low

quality-of-service (LQOS) messages being transmitted through the multiple level structure from a source node to a designated destination node, a level of the multiple levels including:
one or more groups of nodes, the data messages being transmitted to a group of the one or more groups of nodes on a path to a target, a group of the one or more groups including:
a plurality of nodes, a single data message being transmitted to a node N of the plurality of nodes of a group unilaterally toward the destination level if the node is not blocked and otherwise one or more data messages being transmitted laterally if the node is blocked, the data messages being transmitted based at least partly on quality of service of the messages.

38. A network communicating messages in a sequence of discrete time steps, the network comprising:
a plurality of nodes, the nodes including communication devices that receive messages and send messages, the messages including high quality-of-service (HQOS) messages and low quality-of-service (LQOS) messages; and
a plurality of interconnect lines L interconnecting communication devices at the plurality of nodes, a node N of the plurality of nodes including:
a connection to one or more interconnect lines L_{UN} capable of transmitting a plurality of messages from a device U to the node N;
a connection to an interconnect line L_{VN} for transmitting a message from a device V to the node N;
the network having a precedence relationship $P_N(U,V)$ relating to the node N and the devices U and V such that the device U has precedence over the device V in sending a message to the node N so that for one or more messages M_U at the device U that are directed to the node N via the interconnect lines L_{UN} at a time step t and a message M_V at the device V that is directed to the node N via the interconnect line L_{VN}

also at a time step t , the one more messages M_U are successfully sent to the node N and the node V uses a control signal to decide where to send the message M_V , the precedence relationship $P_N(U, V)$ being determined at least partly by quality of service of the messages.

39. A network comprising:

a plurality of nodes N ; and

a plurality of interconnect lines L connecting the plurality of nodes N in a

predetermined pattern, the interconnect lines carrying messages M and

control signals C , the messages including high quality-of-service

(HQOS) messages and low quality-of-service (LQOS) messages, the

messages M and control signals C being received by a node of the

plurality of nodes at a discrete time step t and the messages M being

moved to subsequent nodes of the plurality of nodes in an immediately

subsequent discrete time step $t+1$, the plurality of interconnect lines L

connecting the plurality of nodes N to include:

a node A having a message input interconnection for receiving a

message M_A , a control input interconnection for receiving a

control signal C_A , a direct message output interconnection to a

node D , a plurality of direct message output interconnections to

a node E , a direct control output interconnection to a device G ,

and a control logic for determining whether the message M_A is

sent to the node D or the node E based on:

(1) the control signal C_A ;

(2) a location of the node A within the plurality of interconnect

lines L ; and

(3) a routing information contained in the message M_A , the

routing information including an indication of quality of

service.

40. A network capable of carrying a plurality of messages M concurrently, the

messages including high quality-of-service (HQOS) messages and low quality-of-

service (LQOS) messages, the network comprising:

4 a plurality of output ports P;
5 a plurality of nodes N, the individual nodes N including a plurality of direct
6 message input interconnections and a plurality of direct message output
7 interconnections, the individual nodes N for passing messages M to
8 predetermined output ports of the plurality of output ports P, the
9 predetermined output ports P being designated by the messages M; and
10 a plurality of interconnect lines in an interconnect structure selectively
11 coupling the nodes in a hierarchical multiple level structure arranged to
12 include a plurality of J+1 levels in an hierarchy of levels arranged from
13 a lowest destination level L_0 to a highest level L_J which is farthest from
14 the lowest destination level L_0 , the output ports P being connected to
15 nodes at the lowest destination level L_0 , the level of a node being
16 determined entirely by the position of the node in the structure,
17 the network including a node A of the plurality of nodes N, a control signal
18 operating to limit the number of messages that are allowed to be sent to
19 the node A to eliminate contention for the predetermined output ports
20 of the node A so that the messages M are sent through the direct
21 message output connections of the node A to nodes H that are a level L
22 no higher than the level of the node A, the nodes H being on a path to
23 the designated predetermined output ports P of the messages M, the
24 control signal being determined at least partly according to message
25 quality of service.

1 41. An interconnect apparatus, comprising:

2 a plurality of nodes; and

3 a plurality of interconnect lines in an interconnect structure selectively

4 coupling the nodes in a hierarchical multiple level structure arranged to
5 include:

6 a plurality of J+1 levels with J an integer greater than 0 in an hierarchy
7 of levels arranged from a lowest destination level L_0 to a
8 highest level L_J with the level of a node being determined
9 entirely by the position of the node in the structure, the
10 interconnect structure transmitting a plurality of multiple-bit

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11 messages entering the interconnect structure unsorted through a
12 plurality of input ports, individual messages M of the plurality
13 of messages being self-routing and including high quality-of-
14 service (HQOS) messages and low quality-of-service (LQOS)
15 messages, the individual messages M moving in a plurality of
16 ways including three ways which are sufficient for the message
17 M to exit the interconnect structure through an output port
18 designated by the message M, movement of the message M
19 being determined by quality of service of the message M, the
20 three ways being:

- 21 (1) the message M enters a node in the interconnect structure
22 from a device external to the interconnect structure, the
23 message M designating one or more designated output
24 ports;
- 25 (2) the message M moves through a node in the interconnect
26 structure to a designated output port, a time T being
27 associated with the node such that the message M
28 arriving at the node is selectively transmitted within the
29 time T of the message's arrival at the node; and
- 30 (3) the message M moves either: (i) through a node U on a level
31 L_k of the interconnect structure to a different node V on
32 the same level L_k in combination with another message,
33 if available, or (ii) moves through the node U on a level
34 L_k of the interconnect structure to a node W on a level
35 L_i nearer in the hierarchy to the destination level L_0 than
36 the level L_k , a time T_U being associated with the node U
37 such that the message M arriving at the node U is
38 selectively transmitted within the time T_U of the
39 message M arrival at the node U.

1 42. An interconnect structure comprising:
2 a plurality of nodes; and

3 a plurality of interconnect lines in an interconnect structure selectively
4 coupling the nodes in a structure, the interconnect structure
5 transmitting a plurality of multiple-bit messages entering the
6 interconnect structure unsorted through a plurality of input ports, an
7 individual message M of the plurality of messages being self-routing,
8 the interconnect structure including:
9 a node E having a first data input interconnection from a node A and a
10 second data input interconnection from a node F distinct from
11 the node A; and
12 a control interconnection between the node A and node F for carrying a
13 control signal to resolve contention for sending messages to the
14 node E, the control signal resolving contention at least partly on
15 the basis of quality of service.

1 43. A method of moving messages through an interconnect structure
2 comprising:
3 providing:
4 a plurality of nodes interconnected in a hierarchy including distinct
5 nodes A, B, C, and D, the nodes A and B being on a level in the
6 hierarchy and the nodes C and D being on a next level in the
7 hierarchy;
8 data interconnect lines B₁ and B₂ coupled from the node A to the node
9 B for sending data from the node A to the node B;
10 a data interconnect line D₁ coupled from the node C to the node D for
11 sending data from the node C to the node D;
12 a data interconnect line D₂ coupled from the node C to the node D for
13 sending data from the node C to the node D;
14 a data interconnect line D₃ coupled from the node A to the node D for
15 sending data from the node A to the node D; and
16 a control interconnect line S coupled from the node C to the node A for
17 sending a control signal from the node C to the node A;
18 detecting a condition at the node C;

19 sending a control signal CS on the line S from the node C to the node A, the
20 control signal being determined by the condition at the node C; and
21 sending a message M arriving at the node A to the node B or the node D on a
22 data interconnect line selected from among the data interconnect lines
23 B₁, B₂, and D₃ depending at least partly on the control signal CS.

1 44. A method according to Claim 43 further comprising:
2 sending the message M from the node A to the node D when the condition at
3 the node C is that no messages are moving from the node C to the node
4 D and a path exists from the node D to the target destination of the
5 message M.

1 45. A method according to Claim 43 further comprising:
2 when the condition at the node C is that a low quality of service (LQOS)
3 message M_{LQOS} arrives at the node C with no high quality of service
4 (HQOS) message, sending the message M_{LQOS} from the node C to the
5 node D on the line D₂ for carrying low quality of service messages and
6 sending the control signal CS on the control interconnect line S to
7 indicate the condition,
8 in response to the control signal CS indicative of the condition, the node A is
9 capable of sending a high quality of service (HQOS) message M_{HQOS}
10 arriving at the node A to the node D on the line B₃ but is not capable of
11 sending a LQOS message to the node D on the line B₃.

1 46. A method according to Claim 45 further comprising:
2 in response to the control signal CS indicative of the condition, the node A can
3 send a LQOS message arriving at the node A to the node B on the line
4 B₂.

1 47. A method according to Claim 43 further comprising:
2 when the condition at the node C is that a high quality of service (HQOS)
3 message M_{HQOS} arrives at the node C with no low quality of service
4 (LQOS) message, sending the message M_{HQOS} from the node C to the

node D on the line D_1 for carrying high quality of service messages and sends the control signal CS on the control interconnect line S to indicate the condition, in response to the control signal CS indicative of the condition, the node A is capable of sending either a high quality of service (HQOS) message or a low quality of service (LQOS) message arriving at the node A to the node D on the line B_3 .

48. A method according to Claim 43 further comprising: when the condition at the node C is that a high quality of service (HQOS) message M_{HQOS} and a low quality of service (LQOS) message M_{LQOS} simultaneously arrive at the node C, sending the message M_{HQOS} from the node C to the node D on the line D_1 for carrying high quality of service messages, sends the message M_{LQOS} to the node D on the line C2 for carrying low quality of service messages, and sends the control signal CS on the control interconnect line S to indicate the condition, in response to the control signal CS indicative of the condition, the node A sends neither a high quality of service (HQOS) message nor a low quality of service (LQOS) message arriving at the node A to the node D on the line B_3 .

49. A method according to Claim 48 further comprising: in response to the control signal CS indicative of the condition, the node A can send a HQOS message and/or a LQOS message arriving at the node A to the node B.

50. A method according to Claim 43 further comprising: selecting the message M from among a message set R including high quality of service (HQOS) messages and low quality of service (LQOS) messages, the messages having a header including quality of service information and information specifying a target destination for ultimately receiving the message.

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1 51. An interconnect structure for communicating data in packets, the
2 interconnect structure comprising:
3 a collection of nodes including distinct nodes A, B, C, and D;
4 a collection of interconnect lines selectively coupling the nodes of the
5 interconnect structure, and
6 a logic for routing packets through the interconnect structure so that:
7 the node A is capable of sending packets to the node B or the node D;
8 and
9 for a packet PA arriving at the node A and a packet PC arriving at the
10 node C, the node C has routing priority over the node A to send
11 messages to the node D in which:
12 routing of the packet PA at the node A depends upon routing of
13 the packet PC at the node C, and
14 routing of the packet PC at the node C depends at least partly
15 on a quality of service of the packet PC.

1 52. An interconnect structure according to Claim 51 wherein:
2 routing of the packet PC at the node C does not depend on routing of the
3 packet PA at the node A;
4 the logic routes the packets depending at least in part on N quality of service
5 threshold values $T_i(A,D)$ for routing data from the node A to the node
6 D, the number N being two or more, the threshold values $T_i(A,D)$
7 being increasing in value from $T_0(A,D)$ to $T_{N-1}(A,D)$;
8 the collection of interconnect lines including control signal lines for carrying
9 control signal information CS(0) to CS(N-1) corresponding to the
10 threshold values $T_0(A,D)$ to $T_{N-1}(A,D)$;
11 a plurality of nodes are capable of sending control signals CS(i) to the node A;
12 on receipt of control information CS(j) at the node A, j being between 0 and
13 N-1, if a packet PA is present at the node A, a path exists through the
14 node D to an acceptable target of the packet PA, and the level of QOS
15 for the node A is at least $T_j(A,D)$, then the node A will send a packet to
16 the node D.

1 53. An interconnect structure according to Claim 52 wherein:
 2 the logic routes the packets depending at least in part on N quality of service
 3 threshold values $T_i(A,D)$ for routing data from the node A to the node
 4 D including the threshold values $T_0(A,D)$ and $T_1(A,D)$;
 5 the collection of interconnect lines including control signal lines for carrying
 6 control signal information $CSI(i)$ corresponding to the threshold values
 7 $T_i(A,D)$ including the control signal information $CSI_0(A,D)$ and
 8 $CSI_1(A,D)$; and
 9 in the presence of control signal information $CS_N(A,D)$, if a packet PA exists
 10 at the node A, a path exists through the node D to an acceptable output
 11 port of the packet PA, and the level of QOS for the packet PA is at
 12 least $T_N(A,D)$, then the node A sends a packet to the node D.

1 54. An interconnect structure according to Claim 52 wherein:
 2 the control signal information $CS(i)$ sent by the plurality of control signal
 3 sending nodes depends at least partially upon the routing of messages
 4 through the node C.

1 55. An interconnect structure according to Claim 52 wherein:
 2 the control signal information $CS(i)$ sent by the plurality of control signal
 3 sending nodes depends at least partially upon the future routing of
 4 messages through the node D.

1 56. An interconnect structure comprising:
 2 a plurality of nodes including the distinct nodes A, B, C, and D;
 3 a collection of lines selectively coupling the nodes of the interconnect
 4 structure, including one or more data carrying lines allowing the node
 5 A to send messages to the node B, one or more data carrying lines
 6 allowing the node A to send data to the node D, and one or more data
 7 carrying lines allowing for the node C to send data to the node D; and
 8 a logic for routing packets through the interconnect structure so that:

9 a message M_C arriving at the node C is not blocked from being routed
10 to the node D by a message M_A arriving at the node A;
11 messages arriving at the node A are routed by a logic associated with
12 the node A to other nodes in the interconnect structure; and
13 the logic at node A uses quality of service information from the
14 messages arriving at node A at least in part to route the
15 messages arriving at node A to other nodes in the interconnect
16 structure

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